Transport of smoke from Canadian forest fires to the surface near Washington, D.C.: Injection height, entrainment, and optical properties

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[1] Smoke and pollutants from Canadian forest fires are sometimes transported over the United States at low altitudes behind advancing cold fronts. An unusual event occurred in July 2002 in which smoke from fires in Quebec was observed by satellite, lidar, and aircraft to arrive over the Washington, D.C., area at high altitudes. This elevated smoke plume subsequently mixed to the surface as it was entrained into the turbulent planetary boundary layer and had adverse effects on the surface air quality over the region. Trajectory and three-dimensional model calculations confirmed the origin of the smoke, its transport at high altitudes, and the mechanism for bringing the pollutants to the surface. Additionally, the modeled smoke optical properties agreed well with aircraft and remote sensing observations provided the smoke particles were allowed to age by coagulation in the model. These results have important implications for the long-range transport of pollutants and their subsequent entrainment to the surface, as well as the evolving optical properties of smoke from boreal forest fires. *INDEX TERMS:* 0305 Atmospheric Composition and Structure: Aerosols and particles (0345, 4801); 0345 Atmospheric Composition and Structure: Pollution—urban and regional (0305); 0360 Atmospheric Composition and Structure: Transmission and scattering of radiation; 0365 Atmospheric Composition and Structure: Troposphere—composition and chemistry; *KEYWORDS:* smoke aerosols, optical properties, entrainment

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1. Introduction

[2] Ozone (O_3) and aerosols transported over long distances can affect air quality at local, regional, and even intercontinental scales. For example, the air over the Mediterranean contains a complicated mix of pollutants transported from Asia, North America, and Europe [*Lelieveld et al.*, 2002]. Saharan dust transported to the United States in the summertime occasionally contributes enough to surface level aerosol concentrations to put portions of Florida out of compliance with U.S. Environmental Protection Agency (EPA) standards for fine particulate matter [*Prospero et al.*, 2001]. Of particular interest in this paper is the transport of pollutants associated with emissions from boreal forest fires. Extensive areas in the boreal forests burn every year with significant interannual variability [*Lavoué et al.*, 2000]. These fires produce large amounts of aerosol and trace gas species, including carbon monoxide (CO) and nitrogen oxides (NO_x), important precursors to the photochemical production of tropospheric ozone [*Goode et al.*, 2000]. For example, enhanced surface level concentrations of CO observed during summer 1995 in the eastern and southeastern United States were attributed to pollutants produced and transported in the plumes from large Canadian forest fires [*Wotawa and Trainer*, 2000]. Transatlantic transport of boreal fire emissions can also be important, with several studies focusing on aspects of an event in August 1998 in which pollutants from fires burning in the Canadian Northwest Territories were transported over the Atlantic and into western Europe. *Forster et al.* [2001] attributed observations of enhanced surface level concentrations of CO at Mace Head, Ireland, and aerosol layers between 3 and 6 km altitude over Germany to this fire event. *Spichtinger et al.* [2001] used satellite imagery to track the transport of a NO_x plume associated with the same burning event. *Fiebig et al.* [2002, 2003] discuss the evolution of the smoke aerosol optical and microphysical properties for the plume observed in this event.

[3] Here we discuss a case of smoke from Canadian forest fires transported in an initially midtropospheric altitude plume that was observed at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC, 39.02°N, 76.86°W, near

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